Chapter 1. What are MFC/R2 and the MFC/R2 protocol module for Unicall

MFC/R2 is a telephony signaling protocol, which dates back over 50 years. Its full name is the Multifrequency Compelled R2 Signaling System. It was originally used to provide register to register (i.e. switch to switch) signaling over analogue copper pair wiring at a higher speed than had been possible with pulse dialing. It was widely used for international circuits, and many national ones. Later, with the advent of E1 PCM trunks, MFC/R2 was adapted for use over this new medium. Though seemingly a relic from the past at a time when SS7 and ISDN are widely deployed, digital MFC/R2 over E1 trunks is still heavily used in many countries.

This MFC/R2 software is implemented as a protocol module within the Unicall framework. Unicall is a unified call processing API, allowing multiple telephony signalling protocols to be used by the same applications source code.

The MFC/R2 protocol module for Unicall supports the MFC/R2 variants used in most parts of the world. Additional variants may be added in a simple manner. Quite a few installations currently use this software, some with very heavy call volumes. However, each country as its own variant of MFC/R2, and these variants sometimes vary a little within country. Some variants have received much more thorough testing than others.

Chapter 2. An introduction to MFC/R2

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This section provides and introduction to how the MFC/R2 protocol works. It is intended to help those not familiar with MFC/R2 who need enough understanding to debug a new installation which is not working properly. If you need a more detailed description of the protocol you should obtain copies of the ITU-T Q.400 series specifications, and any national specifications which might be applicable. Although the ITU defined MFC/R2 internationally, few countries use the protocol exactly as defined by the ITU. It is generally necessary to check national specifications for an exact definition of the local MFC/R2 variant.

Signal types in MFC/R2

MFC/R2 was originally used to provide register to register signaling over analogue copper wiring at a higher speed than had been possible with pulse dialing. To do this, MFC/R2 continued to use DC voltage conditions on the line to indicate things like seize and clear, as older systems had done. However, it replaced the decadic pulsed digits of older systems with dual tone signals. The tone generators and decoders are only needed during call setup, and may be reallocated to other circuits once a call is established. Monitoring for the end of the call is handled by the line signals alone. This was critically important when MFC/R2 was first developed, as the tone processing hardware was very expensive, and needed to service as many calls as possible.

As time passed there was a need to operate MFC/R2 over analogue circuits which had no DC continuity. A 3825Hz tone was introduced for this purpose. The line signal was encoded as the prescence or abscence of this tone on the wires. 3825Hz may be considered an out-of-band tone on these older circuits. When E1 circuits were introduced, MFC/R2 was adapted to work over them. Thus, today there are both analogue and digital versions of MFC/R2. The analogue versions are now rarely used. The digital version, over E1s, is still widely used.

MFC/R2 channels may be configured for only incoming calls or only outgoing calls. However, most national variants permit each channel to handle both

incoming and outgoing calls. The protocol does not avoid collisions, but can gracefully detect a collision and reallocate a call to another channel.

The terms *forwards* and *backwards* are heavily used in descriptions of MFC/R2. Forwards is the direction from the calling party to the called party. Backwards is from the called party to the calling party.

Line signals for the digital version of MFC/R2 (defined in ITU-T Q.421)

The MFC/R2 digital line signals are the ABCD bits of the channel associated signaling (CAS) in timeslot 16 of an E1. They represent the states of the line, and are similar to the states of an analog line. In general, only bits A and B are used. In most systems bits C and D are set to fixed values, and never change. There are some national variants where bit C or D may be used for metering pulses.

Table 2.1. Forward line signals, digital version

CAS bit	Meaning	Values
A	Line status	1=on hook, 0=off hook
B	Condition	1=failure, 0=normal
C	Fixed	Always 0
D	Fixed	Always 1

Table 2.2. Backward line signals for digital MFC/R2

CAS bit	Meaning	Values
A	Line status	1=on hook, 0=off hook
B	Condition	1=seized, 0=idle
C	Fixed	Always 0
D	Fixed	Always 1

Table 2.3. ITU-T Q.421/Table 1

Circuit state	Forward AB	Backward AB
Idle/Released	10	10
Seized	00	10
Seizure acknowledged	00	11
Answered	00	01
Clear-back	00	11
Clear-forward (before clear-back)	10	01
Clear-forward (after clear-back)	10	11

Blocked	**10**	**11**

Charging signals (line signaling with metering, Q.400 Series Supplement No.6)

During the conversational phase of a call, some countries send metering pulses from the called switch to the calling switch. These are encoded as pulses of the line signals, typically pulsing backwards bit A. To avoid confusion with clear-back, a new table was defined in Supplement No.6 of the ITU specifications. This replaces the clear-back state with a forced-release state.

Table 2.4. ITU-T Q.400 series supplement No.6/Table 1

Circuit state	Forward AB	Backward AB
Idle/Released	**10**	**10**
Seized	**00**	**10**
Seizure acknowledged/meter	**00**	**11**
Answered/meter	**00**	**01**
Clear-forward (forced release)	**10**	**00**
Clear-forward (before clear-back)	**10**	**01**
Clear-forward (after clear-back)	**10**	**11**
Forced release	**00**	**00**
Blocked	**10**	**11**

Line signals for the analogue version of MFC/R2 (defined in ITU-T Q.411)

The analogue line version of MFC/R2 is rarely used these days, and will not be covered in detail. It uses only a single line signaling bit. This was originally encoded by DC conditions on the line. Later it was encoded as the prescence or abscence of a 3825Hz tone on the line. This frequency carries well enough on even poor quality lines to function properly on a single link in the chain, and allowed paths without response down to DC to be used. If passed through an E1 link without translation, this bit is usually carried in the A bit of the CAS bits. The remaining bits (B, C and D) are fixed, so the line signals are represented as 1XXX and 0XXX.

Inter-register signals (defined in ITU-T Q.441)

The inter-register, or inter-switch, signals in MFC/R2 signaling are encoded as the prescence of 2, and only 2, out of 6 specific tones, spaced at 120Hz intervals. Two sets of tones are defined - one for forward signals, and one for backward signals. There are 15 combinations of 2 out of 6 tones, so there are 10 signals for the digits 0 to 9, and 5 additional signals available for supervisory purposes.

Some of the Bell system signaling schemes use similar 2 out of 6 tones signals. However, the actual frequencies used are different. Also, the Bell system uses only one set of 6 frequencies. MFC/R2 uses a separate set of frequencies for the forward and backwards directions.

The inter-register signals are send in-band. They may pass transparently through several nodes in the network between the two terminating switches. The signals are arranged in groups. When a call begins the calling end uses group I signals, and the called end uses group A. The called end may tell the calling end to switch to using group II and group B signals, or to switch back to group A. In some countries there are also groups III and C, used for caller number transfer. Groups III and C do not exist in the ITU specifications.

MFC/R2 uses a system called compelled signaling. To ensure the sending end never sends signals too fast, each signal from the sending end results in an acknowledgement from the receiving end. The sending end is instructed signal by signal what it should send next - a dialed digit, a digit of caller ID, etc.

Table 2.5. ITU-T Q.441/Table 6 - group I forward signals

MF	Designation	Meaning
1	I-1	Digit 1 (Language: French, if first signal sent in intl. link)
2	I-2	Digit 2 (Language: English, if first signal sent intl. link)
3	I-3	Digit 3 (Language: German, if first signal sent in intl. link)
4	I-4	Digit 4 (Language: Russian, if first signal sent in intl. link)
5	I-5	Digit 5 (Language: Spanish, if first signal sent in intl. link)
6	I-6	Digit 6 (Language: Spare, if first signal sent in intl. link)
7	I-7	Digit 7 (Language: Spare, if first signal sent in intl. link)
8	I-8	Digit 8 (Language: Spare, if first signal sent in intl. link)
9	I-9	Digit 9 (Discriminating digit, if first signal sent in intl. link)
10	I-10	Digit 0 (Discriminating digit, if first signal sent in intl. link)
11	I-11	Country code indicator, outgoing half-echo suppressor required
12	I-12	Country code indicator, no echo suppressor required
13	I-13	Test call indicator (call by automatic test equipment)

14	I-14	Country code indicator, outgoing half-echo suppressor inserted
15	I-15	Signal is not used

Table 2.6. ITU-T Q.441/Table 7 - group II forward signals

MF	Designation	Meaning
1	II-1	Subscriber without priority
2	II-2	Subscriber with priority
3	II-3	Maintenance equipment
4	II-4	Spare
5	II-5	Operator
6	II-6	Data trannsmission
7	II-7	Subscriber (or operator without forward transfer facility)
8	II-8	Data transmission
9	II-9	Subscriber with priority
10	II-10	Operator with forward transfer facility
11	II-11	
12	II-12	
13	II-13	Spare, for national use
14	II-14	
15	II-15	

Table 2.7. ITU-T Q.441/Table 8 - group A backward signals

MF	Designation	Meaning
1	A-1	Send next digit (n+1)
2	A-2	Send last but one digit (n-1)
3	A-3	Address-complete, changeover to reception of Group B signals
4	A-4	Congestion in the national network
5	A-5	Send calling party's category
6	A-6	Address-complete, charge, set-up speech conditions
7	A-7	Send last but two digit (n-2)
8	A-8	Send last but three digit (n-3)
9	A-9	Spare, for National use
10	A-10	
11	A-11	Send country code indicator
12	A-12	Send language or discrimination digit

13	A-13	Send nature of circuit
14	A-14	Request for information on use of an echo suppressor
15	A-15	Congestion in an international exchange or at its output

Table 2.8. ITU-T Q.441/Table 9 - group B backward signals

MF	Designation	Meaning
1	B-1	Spare, for national use
2	B-2	Send special information tone
3	B-3	Subscriber's line busy
4	B-4	Congestion (after changeover from Group A to B)
5	B-5	Unallocated number
6	B-6	Subscriber's line free, charge
7	B-7	Subscriber's line free, no charge
8	B-8	Subscriber's line out of order
9	B-9	
10	B-10	
11	B-11	
12	B-12	Spare, for National use
13	B-13	
14	B-14	
15	B-15	

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Where are the signals and supervisory tones generated, and how are they used?

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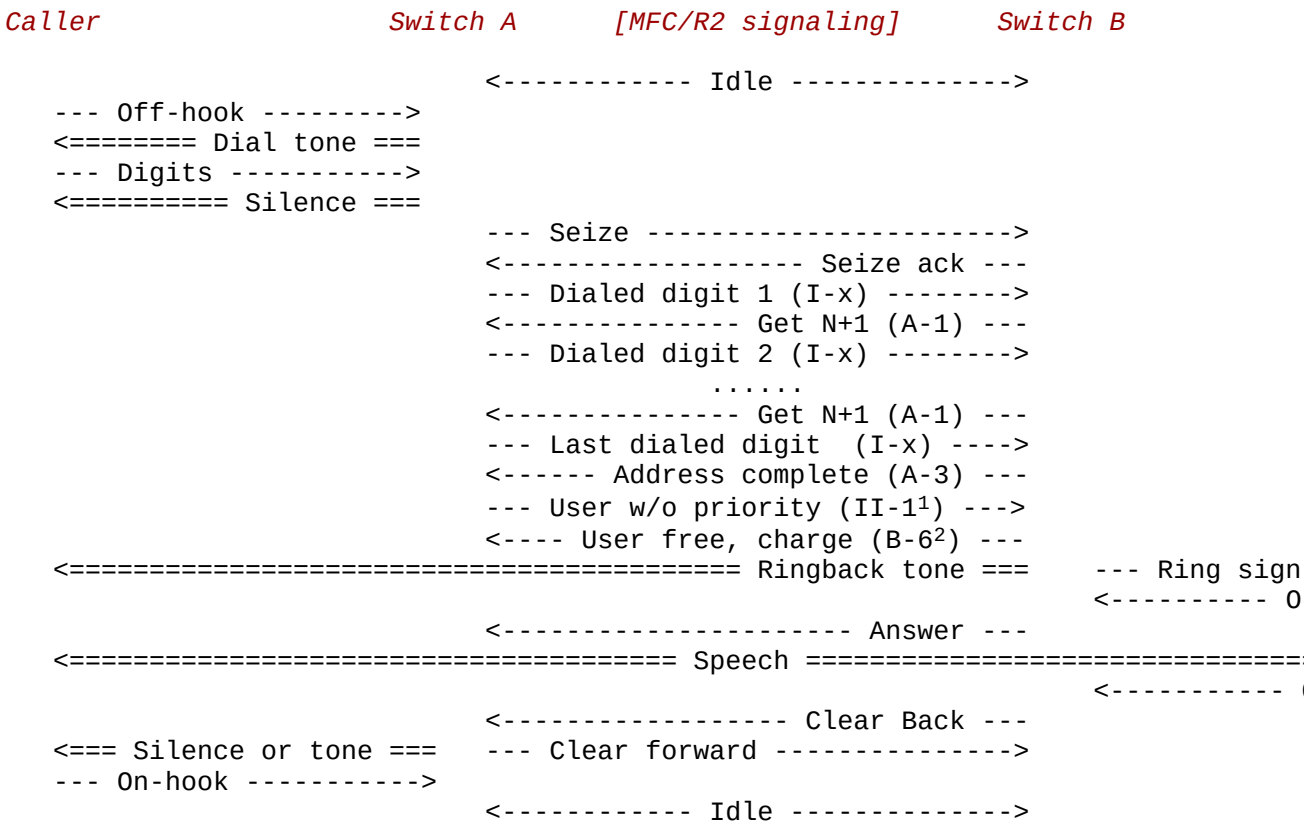
Where are the signals and supervisory tones generated, and how are they used?

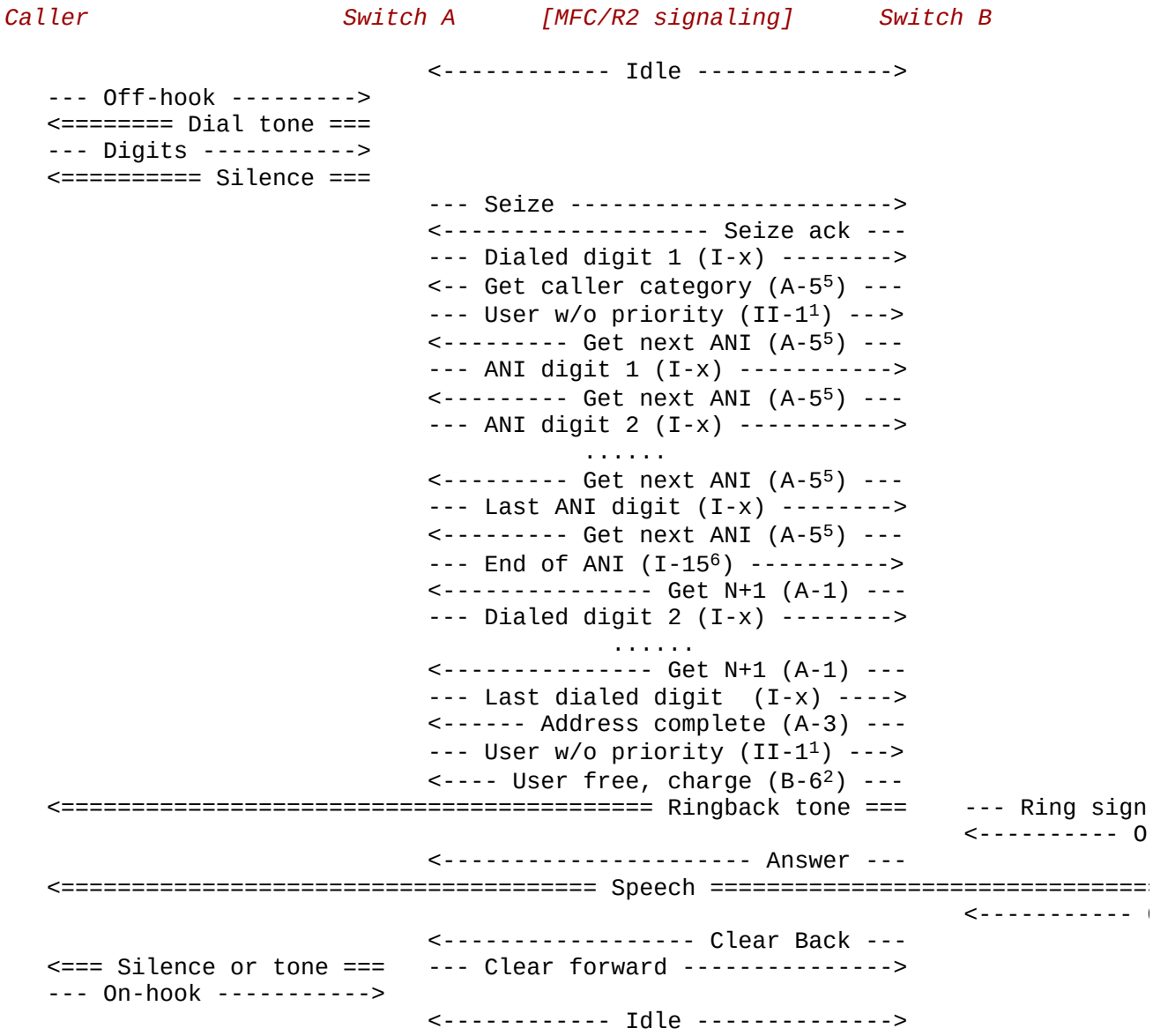
The following call scenarios are based on scenarios in the ITU specifications. Note that around the world things may vary quite a bit from these call scenarios. For example, the busy tone is shown as being generated from the caller's local switch. In some systems it is generated from the called party's local switch. The signals used for various purposes are often different.

The signaling between the switches and the telephones could be by DTMF or pulse dialling on an analogue pair (FXO/FXS signaling). It could be ISDN signaling, over a BRI connection. It could be a VoIP connection. The actual signals passing between the switches and the telephone will be similar in most cases, and details do not affect the overall discussion of how MFC/R2 works.

The first scenario describes a call where the called party answers and releases the call. There is no transfer of the caller ID.



The next scenario describes a similar call, but this time the ANI (effectively the caller ID) is transferred. When the ring signal is sent to the called party's phone it might carry the ANI with it.



The following describes the difference in clearing a call where the called party answers and the calling party releases the call.

The following describes the difference when the called party's line is available, but nobody answers the phone.

```
<=== Silence or tone ===   --- Clear forward --------------->
                           <------------- Clear back/idle ---
--- On-hook ----------->
                           <------------ Idle -------------->
```

The following describes the difference when the called line is busy. The pattern would be similar if the called line is faulty, or out of service, but the signal set from switch B to switch A would be different.

```
Caller                 Switch A      [MFC/R2 signaling]      Switch B

                           --- User w/o priority (II-1[1]) --->
                           <----------------- Busy (B-3[3]) ---
<========= Busy tone ===   --- Clear forward --------------->
                           <------------- Clear back/idle ---
--- On-hook ----------->
                           <------------ Idle -------------->
```

The following describes the signaling behaviour when meter pulses are sent by pulsing bit A of the CAS ABCD bits, in accordance with Supplement No 6 of the ITU specifications. In this example the called party clears first, causing the additional forced release signal, defined in Supplement No 6, to be sent.

```
Caller                 Switch A      [MFC/R2 signaling]      Switch B

<========================================== Ringback tone ===    --- Ring sign
                                                               <---------- O
                           <---------------------- Answer ---
<=================================== Speech ===================================
                           <----- Metering pulse on bit A ---
                           <----- Metering pulse on bit A ---
                                       ......
                           <----- Metering pulse on bit A ---
                                                               <----------- (
                           <-------------- Forced release ---
<=== Silence or tone ===   --- Clear forward --------------->
--- On-hook ----------->
                           <------------ Idle -------------->
```

- Note 1: This could be any of the categories II-1 through II-10.
- Note 2: This could be any of the status signals B-6 User free/charge, B-7 User free/no charge.
- Note 3: This could be any of the status signals B-3 User busy, B-4 Congestion, B-5 Unallocated.
- Note 4: This timeout is typically 10 cycles of the ring signal.
- Note 5: Signal A-5 is used here as "Get caller category" and "Get next ANI". Most national variants now support this. The first occurance of A-5 within a call is interpreted as "Get caller category", and all subsequent A-5's are interpreted as "Get next ANI".
- Note 6: This depends on the national variant, but I-15 is the most common signal used to terminate the ANI.

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Chapter 3. The MFC/R2 protocol support in Unicall

The Unicall MFC/R2 protocol software currently deals with variants for the following:

- Algeria
- Argentina
- Bahrain
- Bolivia
- Brazil
- Chile
- China
- Colombia landlines
- Colombia cellular
- Czech Republic
- Democratic Republic of Congo
- Egypt
- Ghana
- Honduras
- India
- Indonesia
- Iraq
- ITU
- Korea
- Kuwait

- Malaysia
- Mexico
- Nigeria
- Panama
- Philipinnes
- Romania
- Saudi Arabia
- Singapore
- Thailand
- Venezuela
- Vietnam

MFC/R2 is also used in Australia, Belgium, Costa Rica, Ecuador, Finland, Greece, Guatemala, Israel, New Zealand, Paraguay, Peru, South Africa, Uruguay and various former iron curtain countries,

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Setting the protocol variant.

The protocol variant setting for MFC/R2 has the following parameters:

- The national variant code.
- The maximum expected number of ANI digits.
- The expected number of dialed digits.
- An optional parameter, composed of bits, which must be OR'ed together, as follows:
  - 1 - Play progress tones. These are usually handled by the far end switch, but may need to be sent as audio through the channel on some systems.
  - 2 - Play disconnect tone. The disconnect tone is usually handled by the far end switch, but may need to be sent as audio through the channel on some systems.
  - 4 - Play ringback tone. The ringback tone is usually generated by something downstream of the MFC/R2 software, but may need to be generated here on some systems.
  - 8 - Get ANI after DNIS. The usual behaviour for incoming calls is to get the calling party category and the ANI as soon as possible, and to get the DNIS afterwards. This doesn't work on all systems, so the option to reverse this behaviour is provided.
  - 16 - Use immediate accept. Most variants of MFC/R2 offer a way to go directly to the call accepted state, bypassing the use of group B and II tones. This option enables the use of that feature for incoming calls.

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What if some incoming calls work, and some fail?

What if some incoming calls work, and some fail?

In some installations, calls from certain numbers work reliably, while calls from other numbers never get through. There are two common reasons for this.

In a typical customer premises installation of R2, the number of dialled digits will be same for every call. If you specify the expected number of dialled digits to be greater than this number, you may get trouble. When calls from some locations arrive, the dialled number may be correctly terminated by an "end of dialed number" signal. Calls arriving from other places may never send this signal, and the call setup process may freeze until a timeout causes error recovery. The answer is to set the number of expected digits to the number actually expected. This makes call setup just a little faster too, as it is no longer necessary to exchange the "end of dialed number" signal.

The variants of MFC/R2 differ in the way they deal with the caller ID, or ANI, not being available. Some just present a zero length caller number. Some send a special code, to indicate the caller number is not available. It is possible that not every version of these codes is currently implemented in the software. You might, for example, find that incoming international calls fail, because a special code is used. If this happens turn on the logging, and monitor what happens differently with the calls which go wrong. Report it to the author, and it will be fixed.

What if supervisory tones do not work correctly?

If callers do not hear the supervisory tones, like busy or number unobtainable, check the optional fourth parameter to the protocol variant.

The handling of supervisory tones varies from place to place. In most cases tones like number unobtainable, busy and disconnected are generated at the caller's exchange. The ringback tone is generated at the called party's local exchange. This is not always the case, so the software provides options for how supervisory tones are handled.

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