UDC 621. 396. 936

400-MHz Broadband (30 MHz) Mobile Radio Unit

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There is a growing US market for commercial radio equipment with the large bandwidths required by current radio applications. Users want highly functional radio equipment with a bandwidth of 20 MHz or broader has several types of squelch circuits.

Extending bandwidth gives users more communication frequencies and reduces the number of occasions where the retailer has to adjust the equipment for the customer. Extending bandwidth greatly benefits both users and retailers.

The FTM40–3556AT is a new mobile radio unit with a widened UHF (30 MHz) and VHF (26 MHz) band. We improved many circuits to widen these bands. Common squelch circuits are provided as standard. This paper reports the background and key points of the FTM40–3556AT radio unit development as well as the features of the product.

1. Introduction

In the United States, radio equipment is currently used in a wide variety of commercial applications. Radio repeaters cover the whole country. Radio equipment is connected to the public telephone networks. Several types of squelch circuit are used for efficient use of a limited frequency band.

For this reason, single radio units which have multiple communication channels and multiple squelch circuits have become popular. This market affects radio equipment evaluation. The number of channels available, a wide communication frequency range, and the number of tone-squelch circuits are important features.

The FTM40-3556AT was designed to cover a wide bandwidth and to support many functions. Digital coded squelch (DCS), data transfer, and communicationm recording and reproduction functions have been added.

2. Unit outline

The FTM40-3556AT consists of four major sections: transmit, receive, PLL synthesizer, and control.

An H-cross-section die-cast aluminum frame houses the radio PC board on one side, leaving ample space for options and a large heat sink on the other side.

Figure 1 shows the FTM40-3556AT.

The block diagram is shown in Figure 2.

Figure 1. FTM40-3556AT

2.1 Unit functions

2.1.1 Transmit section

The transmit section consists of audio and modulator circuits, a driver circuit, power preamplifier, power postamplifier, automatic phase control (APC) circuit,

and low-pass filter (LPF). The modulator limits the amplitude and frequency of the voice signal from the microphone. The amplitude and band-limited signal then modulates the voltage-controlled oscillator (VCO) output. The carrier generated by the PLL synthesizer is input through the driver circuit to a hybrid preamplifier IC consisting of three transistors.

The carrier power is boosted about 12 W by the hybrid IC, then 40 W or more by the final amplifier. The APC circuit limits the signal level to 35 V and applies it to the antenna through the LPF.

2.1.2 Receive section

The receive section consists of five subsections: an RF amplifier, a frequency converter, an IF amplifier and demodulator, and an audio amplifier. The signal picked up by the antenna is sent to the freaqudncy conversion section, passing the RF amplification section consisting of a band-pass filter (BPF) and RF amplifier. The converter section converts the signal to the first IF using a double balanced mixer (DBM) having excellent cross-modulation characteristic. After further the filtering and amplification, the signal is converted to the second IF, then FM detected and demodulated. The demodulated signal is then sent to the audio amplifier and speaker.

2.1.3 PLL synthesizer section

The PLL synthesizer section consists of two VCOs and a PLL control section.

One VCO generates the carrier and the other VCO generates the first local oscillator signal. The high-frequency signals from the VCOs are input to the PLL control section and their phases compared after dividing. The result of the comparison is fed back to the VCOs for pahse synchronization.

2.1.4 Control section

This radio unit is controlled by an eight-bit CPU mounted in the main unit and a four-bit CPU mounted in the operating.

The CPUs provide the following control functions:

- Main unit CPU

(1) Writes frequency data into the EEPROM
(2) Sends frequency data to the PLL synthesizer section
(3) Controls data transmission, digital recording and reproduction, and other options
(4) Sets customer functions or user
(5) Controls the D/A converter, tone IC, and other peripheral devices

- Operating section CPU

(1) Control the LCD display
(2) Monitors switch closure

2.2 Unit specifications

Table 1 lists the unit ratings and Table 2 lists the performance parameters.

2.3 Unit features

1) Broadband design ensures 30-MHz UHF and 26-MHz VHF.
2) Frequency data can be read in serially from an external PROM programmer or personal computer.
3) The data transmission function and message display LCD enable independent transmission and reception of messages.
4) Optional digital recording and reproducing functions are available.
5) Functions customizable by the retailer or user.
6) Remotely placeable operator panel.
7) Up to 96 channels with extension ROM.

3. Development objectives

The FTM40-3556AT is Fujitsu Ten's first broadband voice and radio unit for export to be equipped with digital coded squelch (DCS). Fujitsu TEN placed special emphasis on the design of the DCS for improved encoding and decoding stability. To achieve broad-band characteristics, we placed special emphasis on the broad-band VCO design. For the message data transmission, we develop a radio device which can send and receive message data without the use of any other devices.

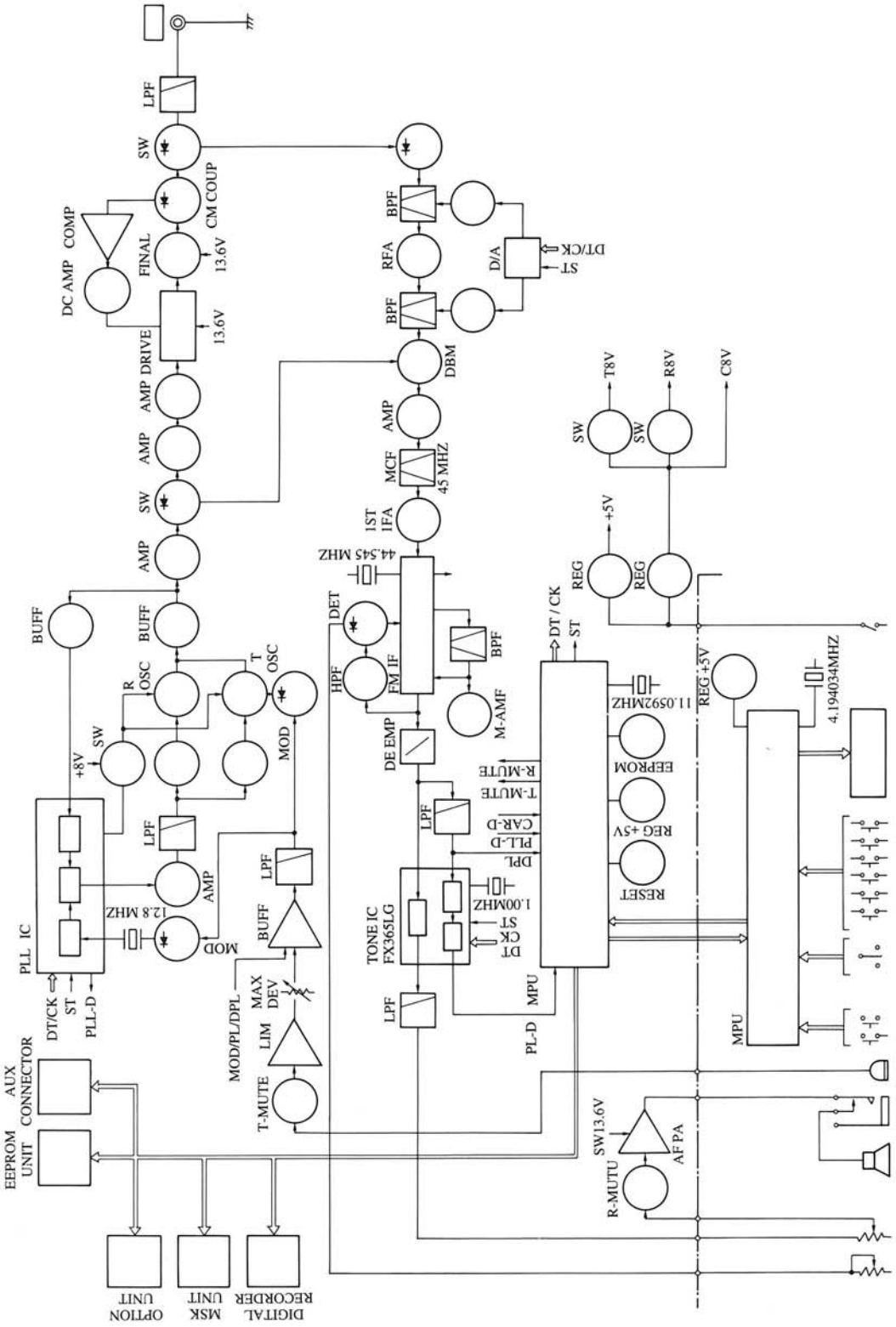


Figure 2. Block diagram

Table 1. FTM15-3556AT/FTM40-3556AT ratings

Parameter	FTM15-3596AT	FTM40-3556AT
Frequency	148 to 174 MHz	450 to 480 MHz
Maximum frequency space	26 MHz	30 MHz
Channel separation	5 KHz, 12.5 KHz	12.5 KHz
No. of channels	16 (99 options)	
Waveform type	16KOF3E	
Maximum frequency deviation	±5 Hz	
Antenna impedance	50 Ω	
Talk system	Press-to-talk (half-duplex possible)	
Receive system	Double superheterodyne	
Tone	CTCSS, DCS	
Power supply	13.6 V	
Temperature range	–30°C to +60°C	
Dimensions	160 x 55 x 222 mm	
Weight	2 kg	

Table 2. FTM15-3556AT/FTM40-3556AT performance parameters

Transmission output	35 W
Frequency stability	±5 x 10^{-6} or less
Spurious radiation	–70 dB or less
Standard modulation input	–50 dBm
Transmitter distortion	3% or less
Send S/N	45 dB or more
Receive sensitivity	–4 dBμV or more
Receive bandwidth	12 kHz or more (–6 dB band)
Receive selectivity	25 kHz or less (-70 dB band)
Spurious sensitivity	75 dB or more
Blocking effect	75 dB or more
Cross modulation	75 dB or more
Receiver distortion	3% or less
Receive S/N	40 dB or more
Maximum receive output	1.5 W or more (8Ω)
Power consumption (send)	8 A or less
Power consumption (receive)	450 mA or less
Stand-by power consumption (receive)	350 mA or less

3.1 Digital coded squelch (DCS)

3.1.1 DCS outline

The DCS system was developed by Motorola. It is a digital continuous tone squelch system, which as well as CTCSS has become popular in the United States, Canada, and Australia.

Motorola patented the system under the trade name Digital Private Line (DPL).

General Electric calls their system the Digital Call Guard (DCG).

DCS is the generic term and is used by Fujitsu Ten.

DCS has the following features:

(1) 512 codes can be selected using three octal digits.

(2) A turn-off code is used to terminate transmission to eliminate or squelch the squawking noise heard when the RF signal is stopped at the receiver.

3.1.2 Code organization

The DCS data format can be divided into two parts, (1), the code word (data division), (2), and the turn-off code (send end code).

(1) Code word

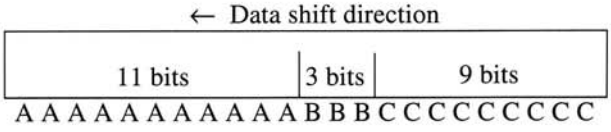
Three blocks consisting of twenty-three bits constitute one code word.

The data transmission speed is 7.5 ms/bit (170 ms/word).

The DCS is not as effective as CTCSS in terms of the receive open attack time (time to open the receive decoder) because the DCS requires an attack time 9 of 170 ms or longer.

(2) Turn-off code

If the microcomputer decodes a turn-off code, the receive audio circuit is immediately muted to squelch the noise tail.



Block A: Error bit detection code
Block B: Fixed code (000)
Block C: Code data (three octal digits: 000 to 777)

Figure 3. DCS data format

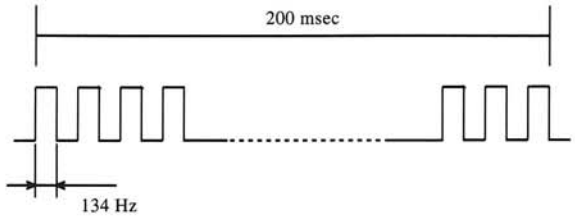


Figure 4. Turn-off code

3.1.3 DCS code overlap

The DCS is acontinuous data transmission system. Unlike ordinary data transmission systems, it does not use bit or frame synchronization.

For this reason, the first data bit cannot be timed and the required data timing may be in error.

Example
0100100010010000110011001001000100100001100110

Code word 146
1100110010010001001000011001100100100010010000

Code word 220
1100100100010010000110011001001000100100001100

Code word 414
0001100110010010001001000011001100100100010010

Code word 422

The result of calculation, shows that the number of available codes is 83.

3.1.4 Maximum and minimum frequencies and frequency deviation

(1) Frequency components

From the calculation, the highest code frequencies are 11.2 Hz and the lowest is 67 Hz.

Since the turn-off code frequency is fixed at 134 Hz, the modulation circuit of radio equipment must be able to handle signals from 11 to 134 Hz.

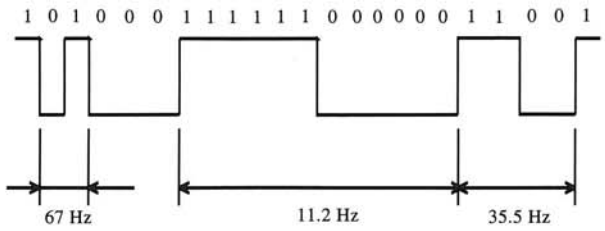


Figure 5. Code word frequencies

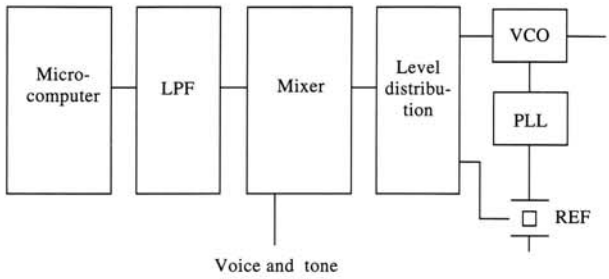


Figure 6. FTM40-3556AT encoder configuration

(2) Frequency deviation

The standard frequency deviation should be ±0.75 kHz.

(Data: 1 = +0.75 kHz, 0 = –0.75 kHz)

3.1.5 FTM40-3556AT configuration

(1) Encoder

(i) LPF

DCS codes output from the microcomputer have completely square waveforms and rich in odd-order harmonics.

The LPF eliminates frequencies outside the voice band and increase the audio signal S/N ratio.

(ii) Mixer

The mixer mixes DCS, voice, and tone signals.

(iii) Modulator

The VCO is used for the modulation by higher frequency components and the REF is used for the modulation by lower frequency components.

The signal is distributed according to the modulation sensitivities of the VCO and REF to obtain an overall flat modulation frequency characteristic.

(2) Decoder

(i) LPF

The LPF prevents malfunction due to voice and noise. In the 56- and 57-type models, the LPF is commonly used for eliminating high-order harmonics output from the encoder.

The low-pass filter's cut -off frequency is about 200 Hz.

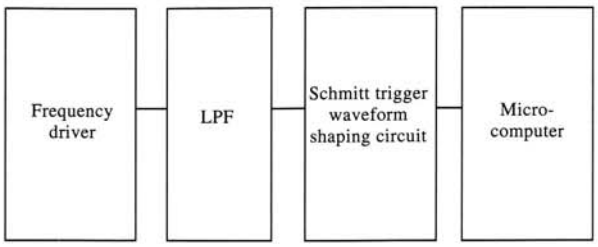


Figure 7. FTM40-3556AT decoder configuration

(ii) Waveform shaping

The LPF has 0.5 volts of hysteresis to eliminate noise.

3.2 Broadband VCO

3.2.1 VCO circuit configuration

The VCO circuit is based on a common-base Clapp oscillator configuratin (Fig. 8). This circuit ensures stable oscillation insensitive to load, supply voltage, and temperature variation.

The voltage-variable element is a varactor diode. Two varactor diodes are connected in series to extend the frequency variation range.

Figure 8 shows the circuit configuration.

3.3 Data transmission

The radio unit can be used for data transmission with the optional 1200 bps modem mounted.

The main section and operator panel section of this unit each contain a microprocessor. With the two processors and the LCD and switches of the operator panel, this radio unit can send and receive message data. (See Figure 9).

3.3.1 Specifications

Table 3 lists the data transmission specifications.

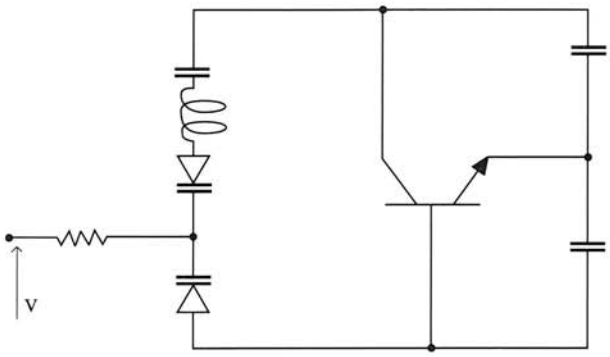


Figure 8. Clapp oscillator circuit

Table 3. Data transmission specifications

Transmission system	NRZ-coded MSK
Data rate	1200 bps
Mark frequency	1200 Hz
Space frequency	1800 Hz

Figure 9. FTM40-3556A operator panel

3.3.2 Message transmission

(1) Message generation

Four front panel keys enable the user to generate messages of up to two lines of ten characters. The keys are described in Table 4. Figure 10 shows a sample message.

(2) Message transmission

The REC key on the front panel is pressed to transmit the message. The transmit process flowchart is shown in Fig. 11.

Table 4. Message keys and functions

CH	Changes the character at the cursor position.
SCAN	Determines the character at the cursor position.
MON	Shifts the cursor left.
PSCAN	Shifts the cursor right.

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Figure 10. Message example

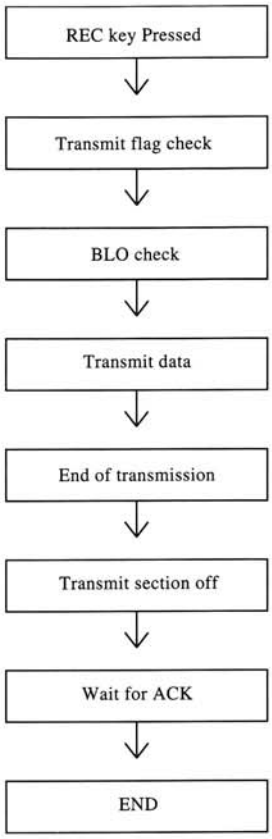

Figure 11. Transmit flowchart

3.3.3 Message reception

(1) Message reception
A message received from a base station is displayed as shown in Figure 12.

(2) Message confirmation
The Check key is pressed to read the message (Fig. 13).

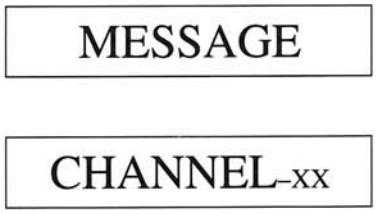

Figure 12. Received message display

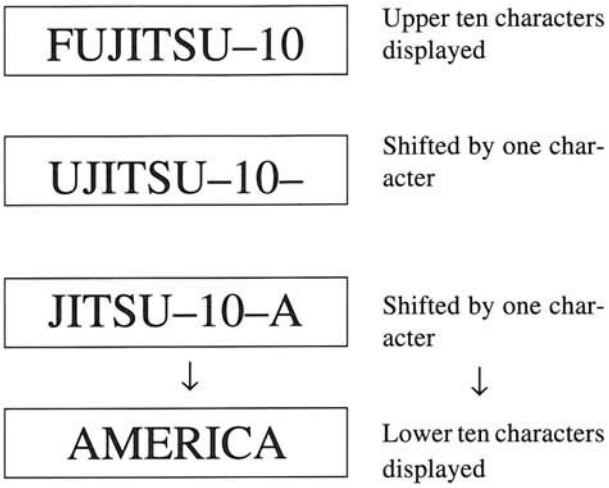

Figure 13. Message confirmation display

Through these procedures, the unit can send and receive character data without the sue of any other device. The operator panel section can be separated for better operability and character readability. Figure 14 shows how the units can be separated.

4. Conclusion

Although the type 56 radio unit introduced here is for export, Fujitsu Ten also provides models for use domestically. These models were designed separately due to the different channel spacing and output power required for the export market. Most sections are common. We plan to extend the common sections to enhance efficiency and reduce costs.

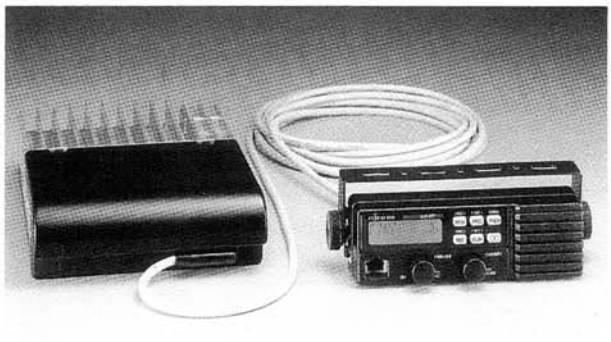

Figure 14. FTM40-3556AT, operating section separated

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