HIGH EFFICIENCY 5 WATT S-BAND TELEMETRY TRANSMITTER USING GALLIUM ARSENIDE FIELD EFFECT TRANSISTORS

Tim Bambridge, Herley Vega Systems

ABSTRACT

A 5-Watt S-Band telemetry transmitter is often the biggest power drain on an airborne telemetry system's power supply. Furthermore, operation is typically limited to supply voltages of 24 Volts or higher. This is because the traditional telemetry transmitter uses a series regulator power supply and silicon bipolar amplifiers. In this paper we describe the design philosophy of a high efficiency telemetry transmitter that uses Gallium Arsenide Field Effect Transistors (GaAs FETs) as the power output stages. The GaAs FETs provide efficiency levels not achievable with silicon bipolar technology. In addition, the power supply uses a switching regulator which provides for constant power drain as a function of input voltage and allows operation down to an input voltage of 18 Volts. Overall, the transmitter can reduce the system's power drain by 30%.

Introduction -Typical Topology of Existing Telemetry Transmitters:

Existing 5-Watt telemetry transmitters fall into two main categories based on how the RF reference frequency is generated.

The first of these is the multiplied reference type where a crystal oscillator is multiplied and filtered in order to provide the required frequency in the 2.2 to 2.3 gigahertz range. This design has the longest history and is still being used in many long running system programs. To change frequency, the crystal has to be replaced and extensive retuning is required at the factory.

The second topology uses a crystal oscillator reference provided to a phase lock loop frequency synthesizer in order to supply any frequency in the 2.2 to 2.3 gigahertz range without the need to replace crystals and retune complex filters.

This paper concerns itself with the synthesizer type of telemetry transmitter where any standard IRIG frequency in the 2.2 to 2.3 megahertz band can be set externally to the unit using a channel select connector. This paper describes how improvements can be made to this topology by incorporating Gallium Arsenide Field Effect Transistors into the RF output stages and using a switching regulator power supply to enable the unit to operate over a wider range of input voltages.

A block diagram for a typical synthesizer 5-Watt transmitter is shown in Figure 1. In this case, incoming DC power is passed thru an EMI filter and then regulated to 20 volts using a standard dissipative series regulator. The 20 volt level is necessary to drive the high power silicon bipolar transistors, which are used for the RF output stages, to produce a power output in excess of 5 watts. The advantage of this approach is simplicity. Series regulators require minimal components and generate no additional EMI which would have to be filtered out. However, to work over a wide input voltage range, the series regulator has to dissipate very high powers. For example, a 5-watt telemetry transmitter drawing 1.5 amps of current will require the series regulator to dissipate 24 watts when operating at an input voltage of 36 volts.

In order to provide efficient operation over a wide input voltage range (approaching 2:1) we need to utilize a power supply which draws a constant power rather than a constant current.

Topology for High Efficiency Telemetry Transmitter:

In order to operate from a wide DC voltage range of 20 to 36 volts DC, the series regulator is replaced with a switching regulator. Also, in order to operate from a step down converter and provide maximum power added efficiency in the RF output stages the silicon bipolar devices have been replaced by gallium arsenide field effect transistors. (FET's).

These high efficiency gallium arsenide FETs have been used in amplifiers for satellite communication systems for over a decade. A block diagram showing the topology of the high efficiency 5-watt telemetry transmitter is depicted in Figure 2. In this case, the input voltage has been extended down to operate from 20 to 36 volts. In this unit the power input return is connected directly to chassis ground similar to the series regulator topology transmitter. The input power is passed through an EMI filter and then onto a buck configuration switching regulator which regulates the voltage to 11 volts. This is then provided to the RF amplifier chain through an output control switch which is used to disconnect the power amplifier remotely and prevents the emission of the transmit frequency until the frequency is accurately locked.

Power Requirements for 5-Watt Telemetry Transmitters:

A comparison of the input power requirements for two 5-watt telemetry transmitters of the type described above is shown in Figure 3. The graphs on the series regular topology are based on published data which indicated a maximum input current of 1.6 amps for the 5-watt telemetry transmitter. The graph is shown with an input current of 1.5 amps (it is assumed that margin exists from the maximum rating). The data for the switching regulator topology is taken from measurements on production HFTT305S telemetry transmitters. The data represents the highest current draw figures for telemetry transmitters providing greater than 6 watts output across the frequency band at 85° C. (85°C represents the worse case operating condition i.e., lowest output power and highest input current requirements).

Comparing the data, we see that the series regulator topology is relatively efficient at an input voltage of 24 volts but that the power drawn by the device increases rapidly to 54 watts at 36 volts. For the switching regulator topology however, the input power drawn from the supply is approximately constant over the total input voltage range of 18 to 36 volts. When operated at 36 volts, this represents a decreased input power drain of over 35%. For the series regulator topology, this represents an additional 19 watts of power that has to be dissipated in the telemetry system. Clearly, considerable savings in system power is possible by incorporating telemetry transmitters utilizing switching regulator topologies.

EMI Considerations On Telemetry Transmitters With Switch Mode Power Supplies:

The trade-off that occurs when using a switching regulator topology is the additional EMI filtering that is required in order to remove the switching frequency. In the HFTT305S a 100 kilohertz switching frequency is utilized. Careful filtering and grounding is essential in order to prevent leakage of the 100 kilohertz switching frequency out of the power lines and to prevent the 100 kilohertz from modulating the transmitted RF signal.

On the HFTT305S an LC filter is used after the switching regulator to reduce the power supply ripple to such a level that the 100 kilohertz side bands are not visible on the RF spectrum when viewed with a resolution bandwidth of 1 kilohertz. [See Figure 4]. This represents a reduction in side band level generated by the power supply of over 70 dB from the carrier. Similarly, LC filters on the input power lines and careful control of ground loops insures that the conducted emissions on the power lines are reduced to a level of better than 20 dB below the specification of MIL-STD-461C. [See Figure 5].

Future Growth In High Efficiency Telemetry Transmitter

A further reduction of 10% in input power requirements is possible by optimizing the switching regulator and the RF power amplifier stages. In order to ensure optimum efficiency for a telemetry systems over wide input voltage ranges, it is important that system designers specify a maximum input power requirement for telemetry transmitters rather than a maximum input current requirement.

A further consideration in complex telemetry systems operating from a common power source is the multiple ground loop interference that can arise from having the power return line directly grounded to the chassis of telemetry transmitters. The next step in the evolution of telemetry transmitters is the isolation of the power return by using a transformer coupled switching power supply as depicted in Figure 6. This will be accomplished when systems designers make power isolation a specification requirement, since the technology is a small step from the existing step down switching regulator topology.

CONCLUSION:

This paper has demonstrated that switching regulator technology and power gallium arsenide FET's can be combined in a production 5-watt S-band telemetry transmitter to meet the conflicting needs of:

1. Wide operating voltage range of 18 to 36 volts.

2. External selection of frequency within the 2.2 to 2.3 Ghz band.

3. Greater than 6-watts output over all conditions.

4. Low EMI emissions.

5. Input power requirements 35% less than the industry standards at 36 volts.

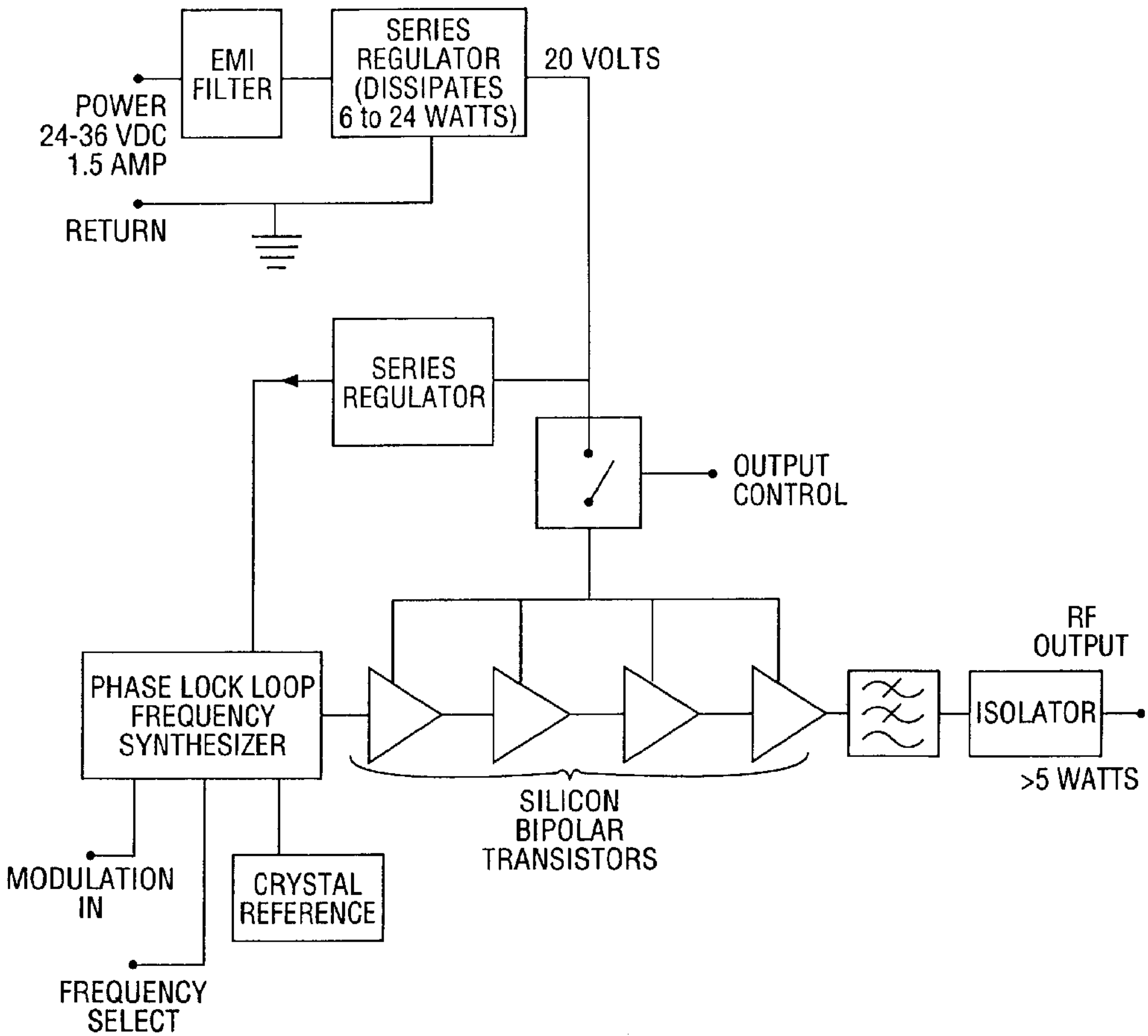

Fig. 1.C25

FIGURE 1: TYPICAL BLOCK DIAGRAM FOR 5 WATT TELEMETRY TRANSMITTER

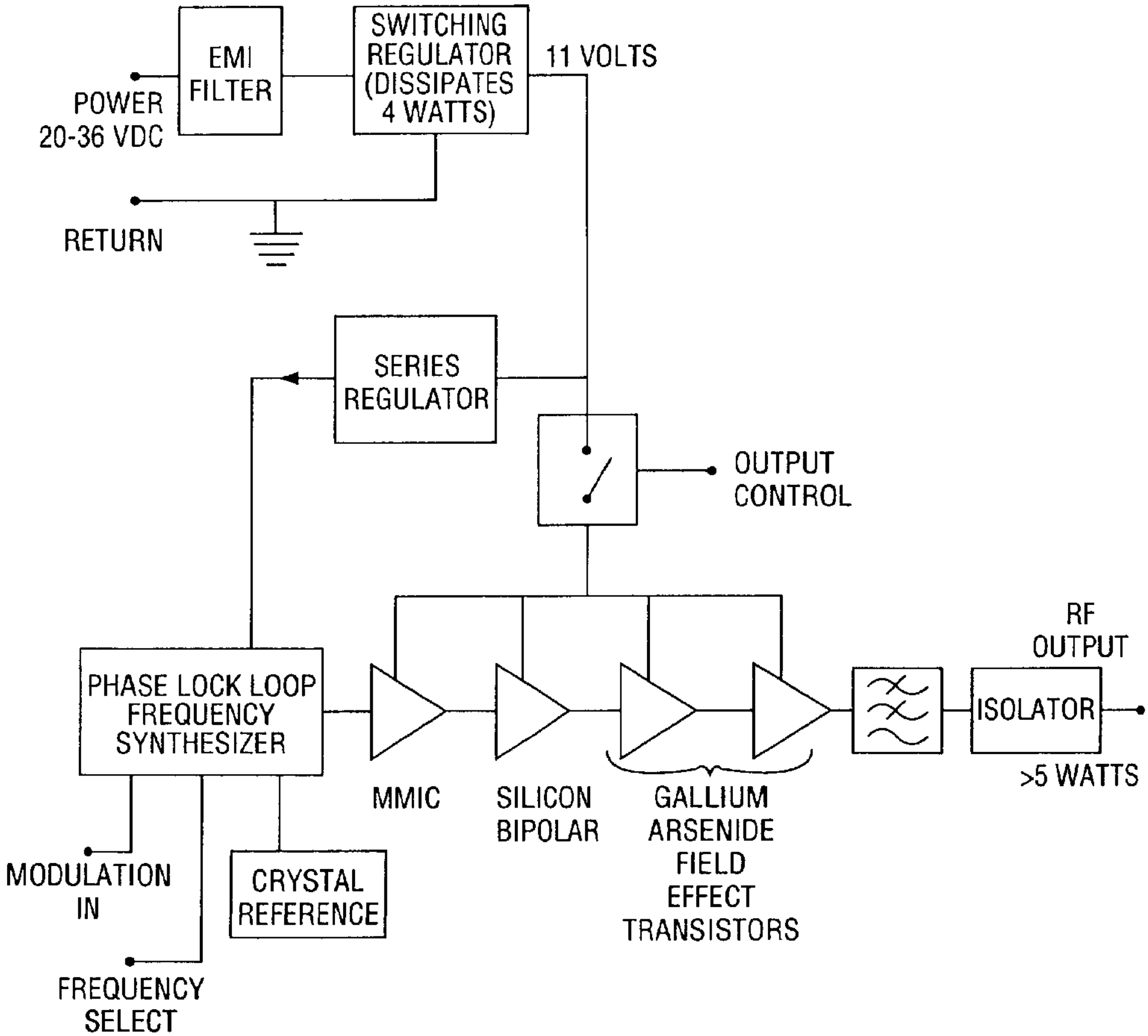

Fig. 2.C25

FIGURE 2: BLOCK DIAGRAM FOR HIGH EFFICIENCY 5 WATT TELEMETRY TRANSMITTER

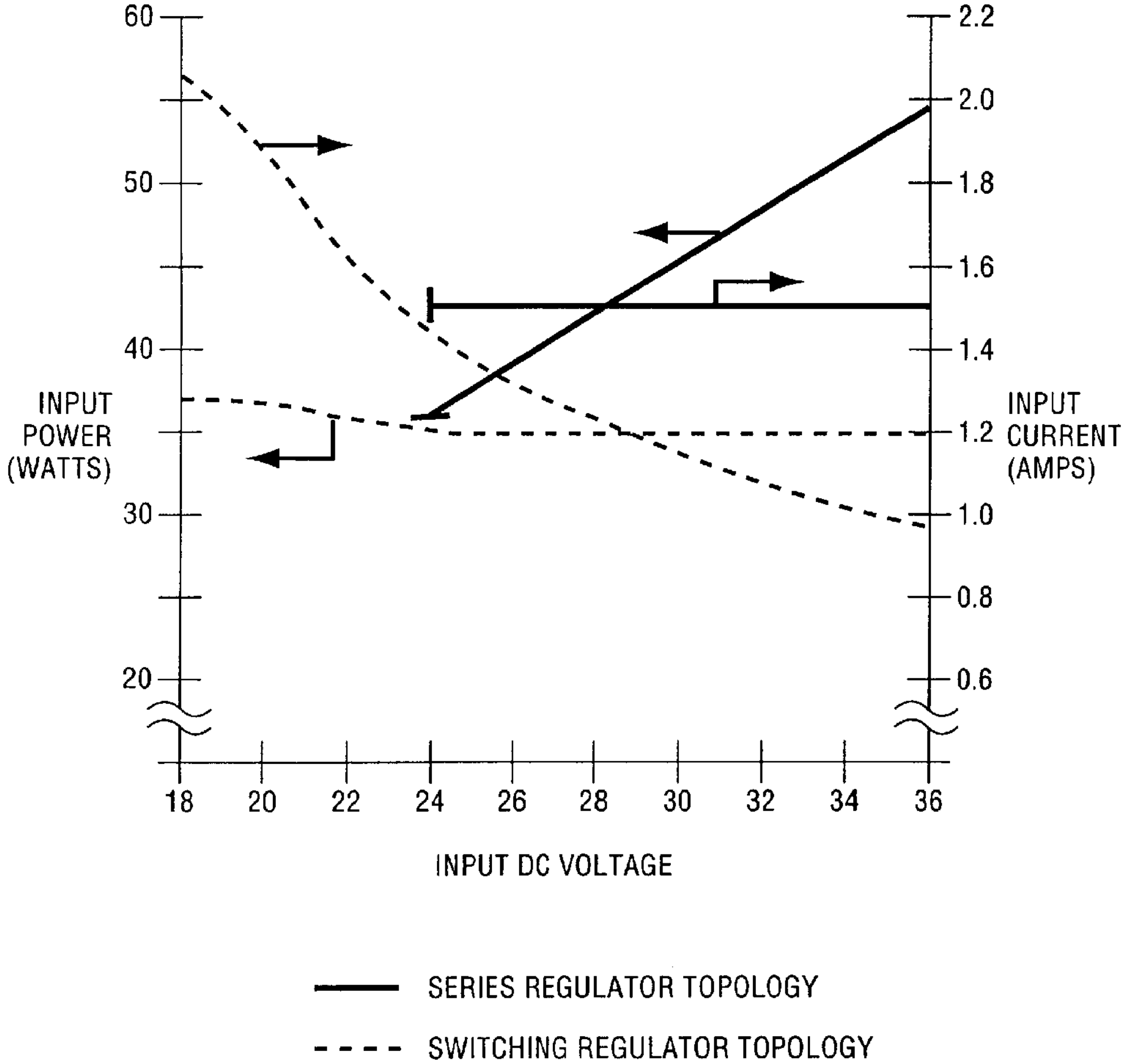

FIGURE 3: COMPARISON OF INPUT POWER REQUIREMENTS FOR TRANSMITTERS WITH SERIES REGULATOR AND SWITCHING REGULATOR POWER SUPPLIES

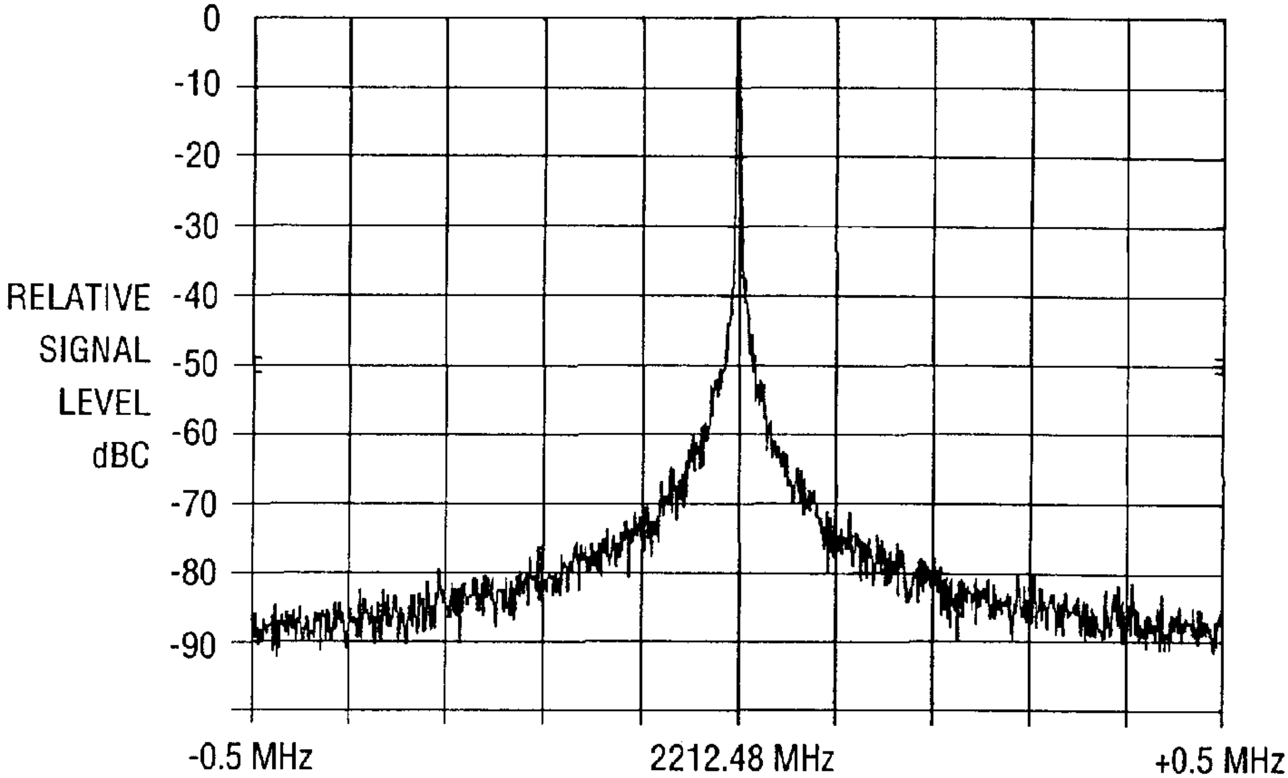

Fig. 4.C25

FIGURE 4: OUTPUT SPECTRUM FOR HFTT305S
(TAKEN WITH RESOLUTION AND VIDEO BANDWIDTHS OF 1kHz)

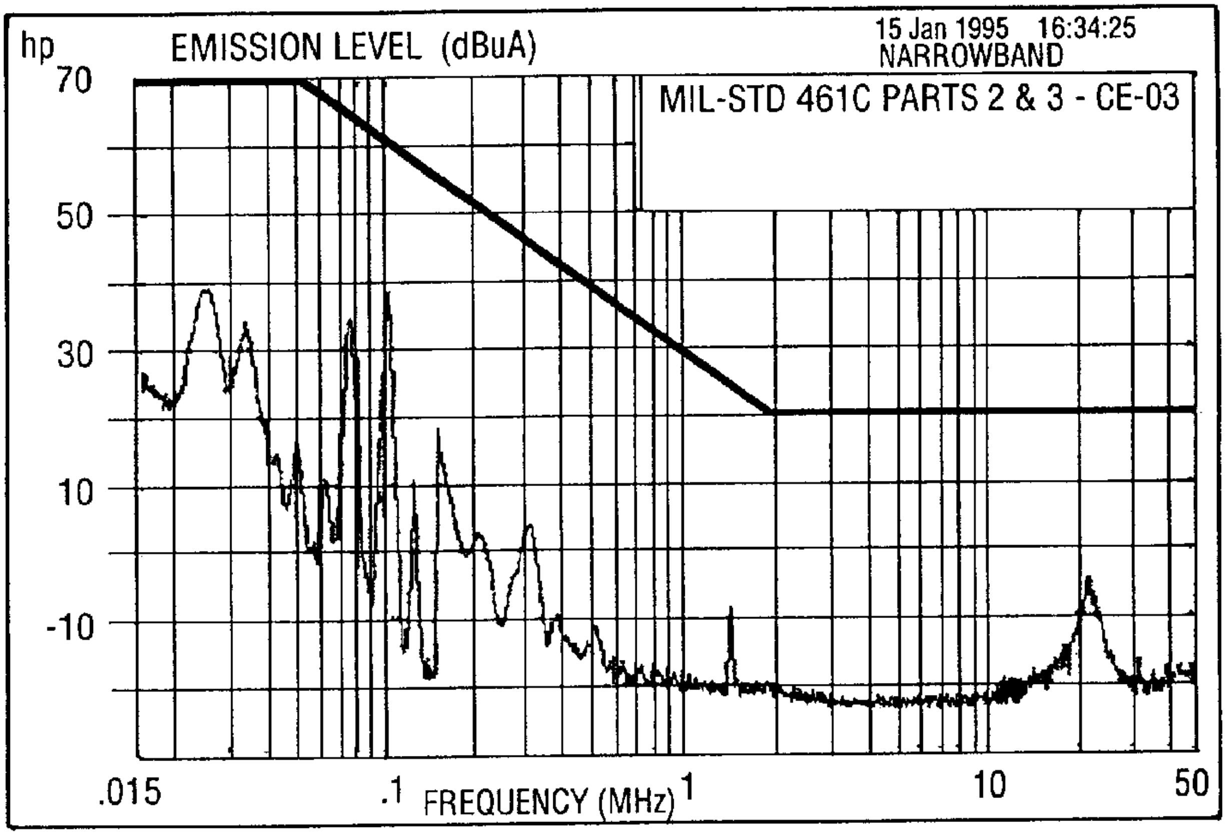

FIGURE 5: CONDUCTED EMISSIONS ON THE POWER LINE FOR THE HFTT305S TELEMETRY TRANSMITTER

Fig. 5.C25

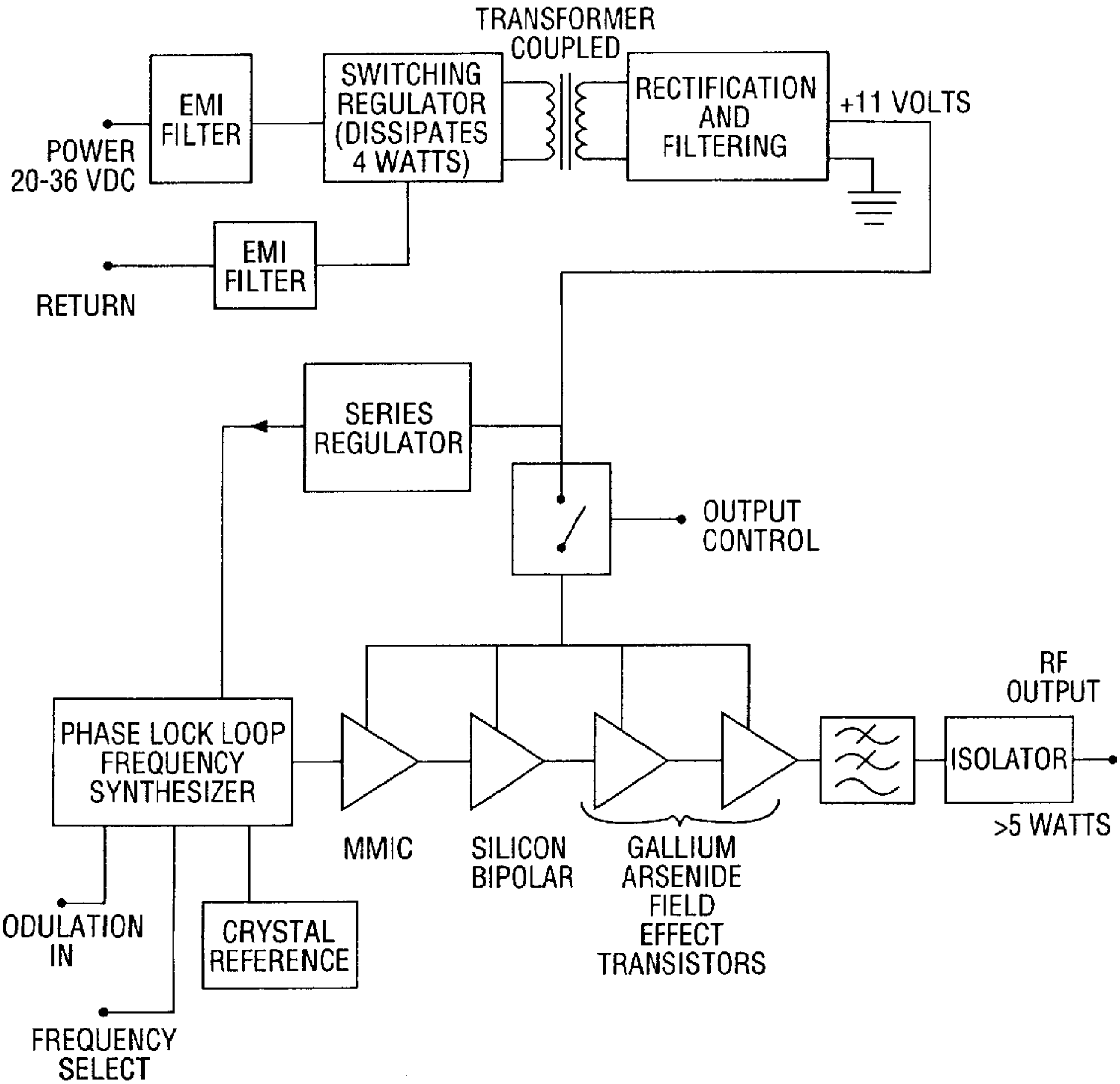

FIGURE 6: NEXT STEP:
BLOCK DIAGRAM FOR HIGH EFFICIENCY 5 WATT
TELEMETRY TRANSMITTER WITH GROUND ISOLATION