Transmitter Modulator and Receiver Shift Modulator

By ANDRAS HAMORI and PAUL L. PENNEY

(Manuscript received November 14, 1967)

The frequency upconverter provides one of the basic building blocks of heterodyne radio systems. In the TD-3 repeater, two waveguide modulators based on a balanced tee hybrid structure provide the required upconverter functions. The transmitter modulator uses high efficiency varactor diodes to convert the IF signal into an RF output. The second modulator, called the shift modulator, provides a 40 MHz shift in frequency between the transmitter local oscillator signal and the receiver local oscillator signal. This circuit uses varistor diodes to obtain simple broadband performance.

I. INTRODUCTION

In the TD-3 radio repeater, two upconverters are used: the transmitter modulator and the receiver shift modulator.[1] Although the electrical requirements for these modulators are quite different, the microwave circuit is similar for both.

In a TD-3 microwave transmitter, an FM modulated 70 MHz IF signal is converted by the transmitter modulator to a microwave signal before amplification and transmission. Because the transmitter modulator is a true upconverter, the output contains two sidebands either of which may be used depending on the channel frequency of the particular repeater.

The TD-3 frequency plan requires a 40 MHz difference between the received and transmitted signals in a repeater bay.[2] Consequently, separate local oscillator signals are required for the receiver and the transmitter. Because of system frequency stability and economy, however, it is very desirable to use the same microwave generator for both applications.* Therefore, the second local oscillator signal is provided by shifting the common generator frequency by 40 MHz

* For reasons explained in Ref. 1, separate microwave generators are used for the receiver and the transmitter of a main station bay.

with the shift modulator. Since this RF to RF conversion is lossy, the shift modulator is in the receiver portion of the TD-3 repeater where the lower local oscillator power is required. Like the transmitter modulator, the shift modulator operates as either a lower sideband upconverter or an upper sideband upconverter, depending on the channel frequency.

II. BASIC STRUCTURE

The transmitter and shift modulators use the same basic microwave structure consisting of a waveguide tee hybrid with coaxial circuits connected to the collinear arms. Having common parts for both modulator designs yields economies in manufacture, maintenance, and repair.

Figure 1 is a block diagram of the common circuit configuration and Fig. 2 is a cross-section of the actual modulator structure, including a connecting IF driver amplifier or 40 MHz oscillator circuit. Figures 3 and 4 are photographs of the equipment. The tee hybrid

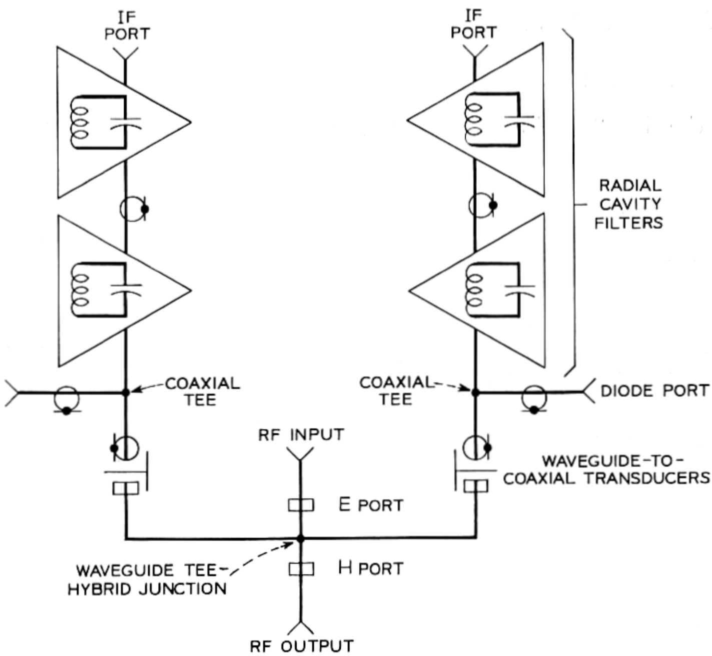

Fig. 1 — Block diagram of common modulator structure.

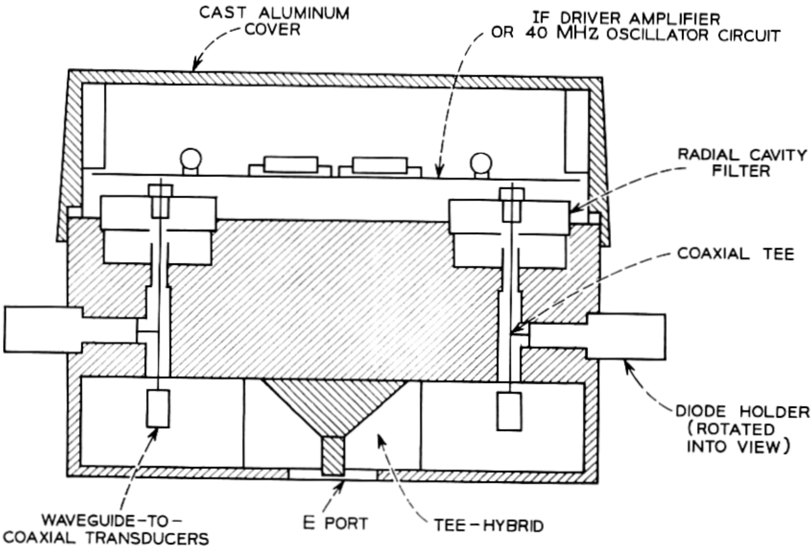

Fig. 2 — Common modulator structure.

provides good isolation between the waveguide input and output ports. The magnitude of this isolation depends only on the physical symmetry of the entire modulator structure and the equality of the impedances of the diodes. Impedance at the input and output ports of the hybrid is controlled by three reactive elements: a post and an inductive iris for matching the source impedance to the E port, and a tuned cone for matching at the H port.

A waveguide-to-coaxial transducer provides the transition to a 50Ω coaxial line at each collinear arm of the hybrid junction. The transducer probe is offset in the guide to provide a good match over the entire TD-3 band. A coaxial-tee circuit provides interconnections among the transducer, the diode, and the low frequency (40 MHz or 70 MHz) port. To obtain best modulator efficiency, microwave energy is prevented from entering the low frequency port by use of a two-section radial cavity filter. This filter provides about 45 dB rejection to frequencies in the TD-3 band, but has little effect at 40 and 70 MHz. The open circuit is obtained at the junction of the coaxial lines by spacing the effective open circuit of the radial cavities one-half wavelength from the junction. This one-half wavelength section of coaxial line is composed of two parts: a quarter wavelength of 50-ohm line and a quarter wavelength of 20-ohm line. The 20-ohm

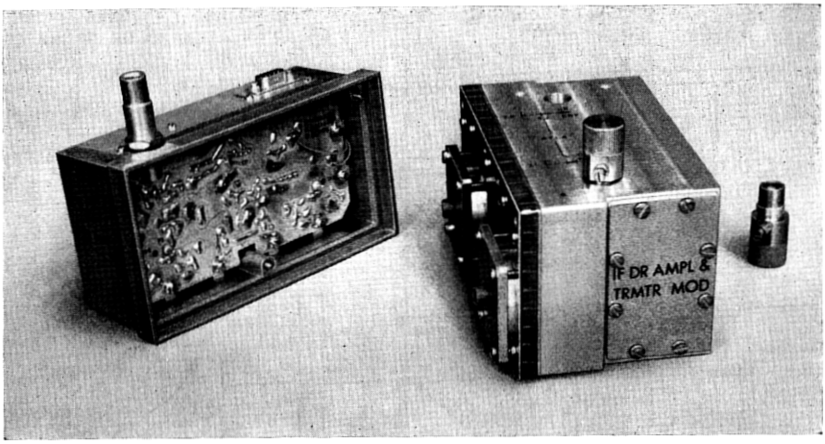

Fig. 3 — Transmitter modulator and IF driver amplifier.

section is used as a transformer and enhances the high impedance provided by the cavities.

The transistor circuits for both modulators are contained in cast aluminum covers that attach directly to the modulator block. In the transmitter modulator, the IF driver amplifier is housed in this cover, while in the 40 MHz shift modulator the cover contains the 40 MHz oscillator circuitry. This construction combines the shortest possible connections between the transistor and modulator circuits with the convenience of easily removable active circuits.

III. TRANSMITTER MODULATOR AND IF DRIVER AMPLIFIER

The transmitter modulator is a balanced parametric upconverter using a matched pair of silicon epitaxial varactor diodes, Western Electric Co.* type 471A. (The equipment described in this article is manufactured for Bell System use only.) The varactor diodes for this modulator circuit were developed especially for this application.[3] The use of a balanced structure based on a tee hybrid junction provides 3 dB more output power than could be obtained with a single diode, and provides 25 dB or more suppression of local oscillator power in the output circuit. The latter feature reduces the selectivity required in the sideband selecting filter. For a local oscillator input power of +20 dBm and an IF (70 MHz) input power of

* Manufacturing and supply unit of the Bell System.

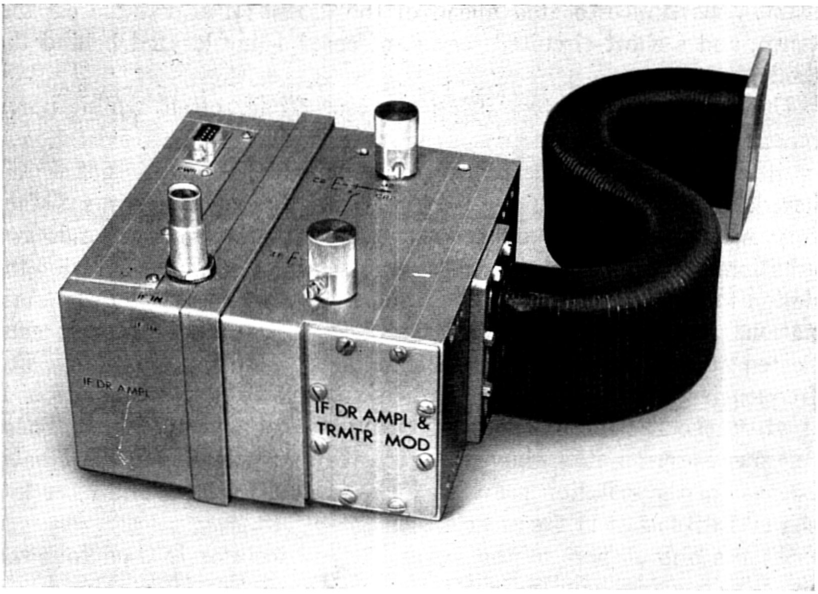

Fig. 4 — Assembled transmitter modulator with connecting waveguide.

about +3 dBm, the microwave output power of the transmitter modulator is at least +8 dBm and some production units reach +12 dBm.

The 471A diodes are mounted in coaxial holders which match the diodes to the 50Ω coaxial lines. Figure 5 shows details of the diode mounting arrangement. The diode matching circuit consists of a fixed

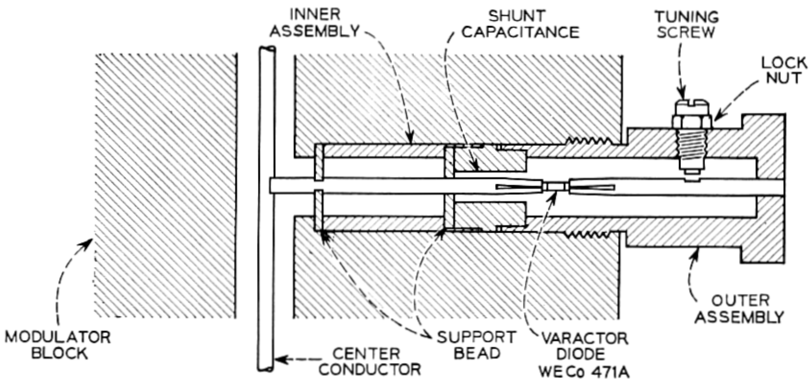

Fig. 5 — Tunable diode mount.

shunt capacitance located ahead of the diode, an adjustable capacitance, and a short-circuited section of coaxial line located behind the diode.

Upconverter modulators using varactor diodes often exhibit parametric oscillations at frequencies where high Q resonances exist. These oscillations can occur at frequencies at which the diode is not terminated. Since the waveguide-to-coaxial transducer provides a satisfactory match only at frequencies in the TD-3 frequency band, two additional kinds of terminations are incorporated in the modulator design to eliminate spurious oscillations. To provide reasonable terminations at frequencies up to 1000 MHz, a 50-ohm resistor is connected at each IF input port as part of the IF driver amplifier. For frequencies above 1000 MHz, a coaxial microwave termination is used on the IF side of each radial cavity as shown in Fig. 6. These microwave terminations have no effect at frequencies in the TD-3 band because of the isolation provided by the radial cavities, and have less than 0.1 dB loss at IF frequencies.

At the output port of the modulator, an isolator is used followed by a waveguide band-pass filter.[1] The band-pass filter selects and passes the desired sideband and reflects the undesired sideband into the isolator where it is absorbed. By absorbing the undesired sideband rather than reflecting it into the modulator for reconversion, a flatter modulator transmission characteristic is obtained.

In the radio transmitter, the IF driver amplifier provides an interface

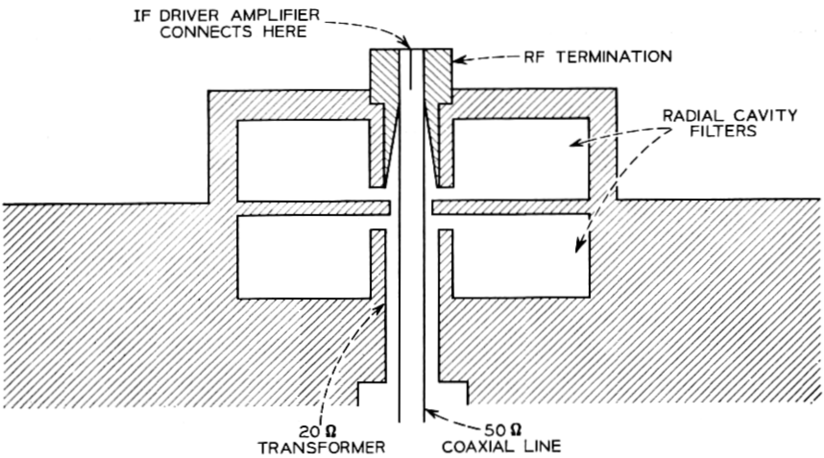

Fig. 6 — RF termination.

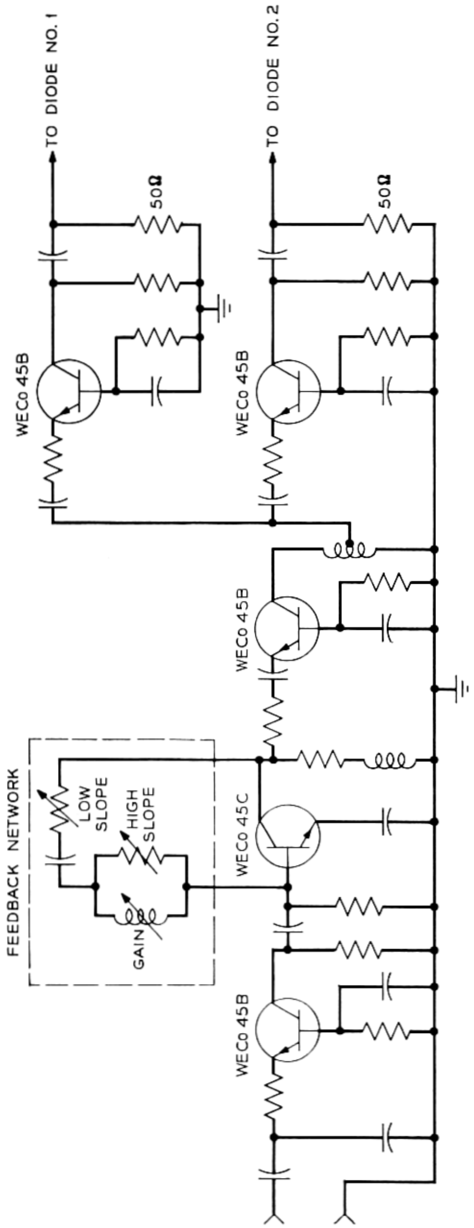

Fig. 7 — IF driver amplifier.

between the limiter and the transmitter modulator.[1] The amplifier provides about 7 dB gain from the 75-ohm input to each of two 50-ohm outputs with transmission flatness better than 0.03 dB over the 70 ±10 MHz band. Figure 7 is a simplified diagram of the circuit used. It consists of five stages with a common base intput stage for impedance matching. The input return loss is better than 35 dB. The second stage is a common emitter amplifier with shunt feedback. Adjustment for over-all circuit gain and transmission shape are provided in the feedback network. The output stages use common base configurations. Separate stages are used for each 50-ohm output to provide isolation between the molulator varactor diodes.

The amplifier operates from a regulated −19 volt supply and draws about 120 mA of current. The amplifier is constructed on a printed circuit board and is mounted in a cast aluminum housing which mounts directly on the transmitter modulator structure.

IV. SHIFT MODULATOR AND 40 MHZ OSCILLATOR

The TD-3 shift modulator uses a matched pair of silicon point contact diodes, WECo. type 416C, in a balanced circuit based on a tee hybrid junction. See Fig. 8. Use of a balanced circuit provides 3 dB higher output level and more suppression of the microwave beat frequency input signal than could be obtained with a single diode in an unbalanced circuit. Varistor rather than varactor diodes were selected for this circuit because conversion gain was not required and only a relatively low output was needed.

The 416C diodes are mounted in coaxial holders which provide matching to the 50-ohm line as shown in Fig. 9. A four section low-pass filter is used in front of each diode to suppress by at least 40 dB the microwave second harmonics generated by the diodes. This amount of suppression is required to ensure an adequately low 80 MHz signal at the output of the receiver modulator.[2] This 80 MHz signal is produced in the receiver modulator as a difference product of the second harmonic of the microwave input and the second harmonic of the microwave output signals of the shift modulator.

At the output of the modulator, the desired sideband is selected by a waveguide band-pass filter while the undesired sideband is reflected into the modulator. Because the modulator has a single frequency output, the phase of the reflected sideband is easily optimized to obtain about 1 dB increase in output.

The modulator requires a +17 dBm microwave input and a +17.5

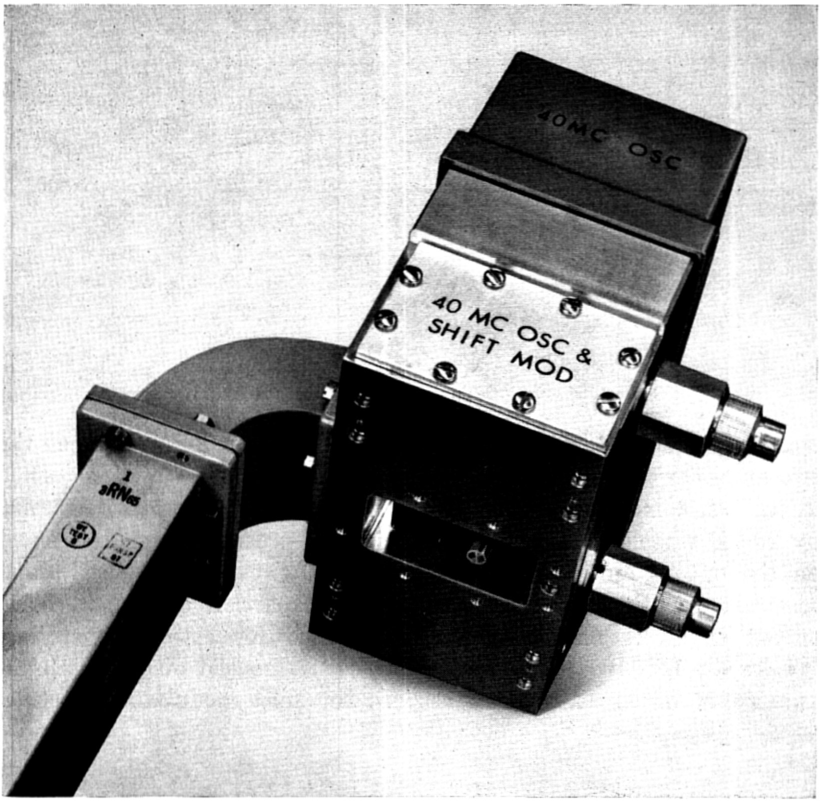

Fig. 8 — Shift modulator and 40 MHz oscillator.

dBm 40 MHz input to provide an output signal of at least +6.5 dBm; some production units reach +8.5 dBm.

The 40 MHz signal is generated in the shift oscillator (see the simplified schematic diagram, Fig. 10.) The circuit consists of three stages: a crystal-controlled oscillator, a tuned common emitter buffer amplifier, and a tuned common emitter output amplifier.

The oscillator stage uses a third overtone crystal which operates in series resonance. A small variable capacitor, C_1, in series with this crystal, provides a frequency adjustment range of about ±500 Hz. A thermistor in the emitter circuit of Q_1 reduces over-all circuit output level variations resulting from temperature changes. The frequency of the oscillator is stable to ±400 Hz for a ±10°F temperature change.

An output power control with about 6 dB range is provided in the

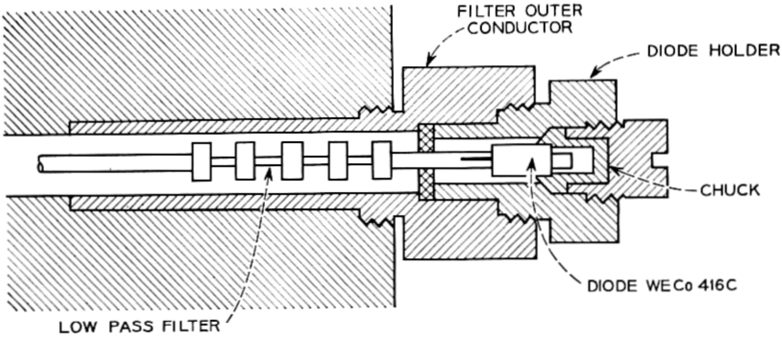

Fig. 9 — Shift modulator diode holder.

circuit by a simple resistive voltage divider (R_1 and R_2) between the two amplifier stages. In order to measure output power and frequency in service, a monitor jack is provided. This access port is decoupled by 20 dB when terminated in 75 ohms and produces negligible effect on the output circuit. When the monitoring tap is not used, it is terminated with a 75-ohm load. A small portion of the 40 MHz output signal is rectified by D_1 and used for external metering.

Like the IF driver amplifier, the circuit is housed in a cast aluminum cover which attaches directly to the shift modulator structure.

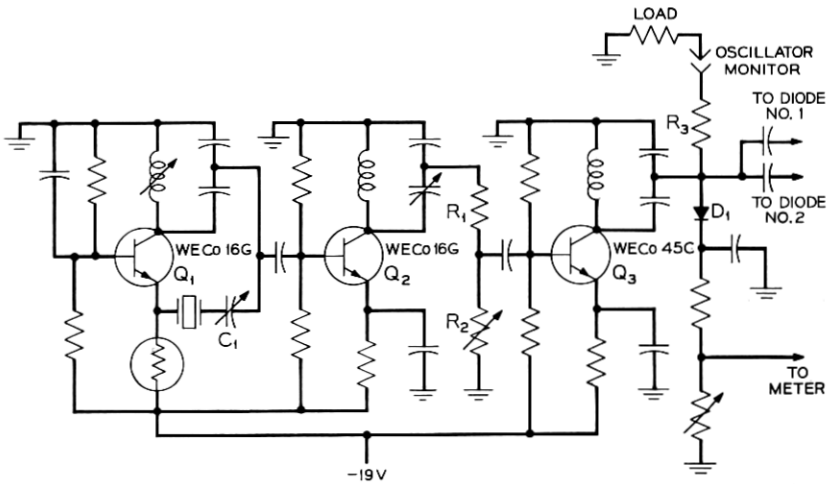

Fig. 10 — 40 MHz shift oscillator.

The total current drain for the circuit is about 55 mA from a −19V regulated supply.

V. ACKNOWLEDGMENTS

The development of the TD-3 transmitter and shift modulators was the combined accomplishment of many individuals. Specifically, the authors wish to acknowledge the contributions of P. I. Sandsmark and R. W. Judkins for the basic modulator circuit design, of S. H. Lee for the IF driver amplified design, and of O. Giust for the 40 MHz oscillator design.

REFERENCES

1. Jensen, R. M., Rowe, R. E., and Sherman, R. E., "Microwave Transmitter and Receiver," B.S.T.J., this issue, pp. 1189–1225.
2. Hathaway, S. D., Hensel, W. G., Jordan, D. R., and Prime, R. C., "The Microwave Radio Relay System," B.S.T.J., this issue, pp. 1143–1188.
3. Elder, H. E., and others, U-Package Microwave Diodes, Section III of "Active Solid State Devices," B.S.T.J., this issue, pp. 1340–1354.